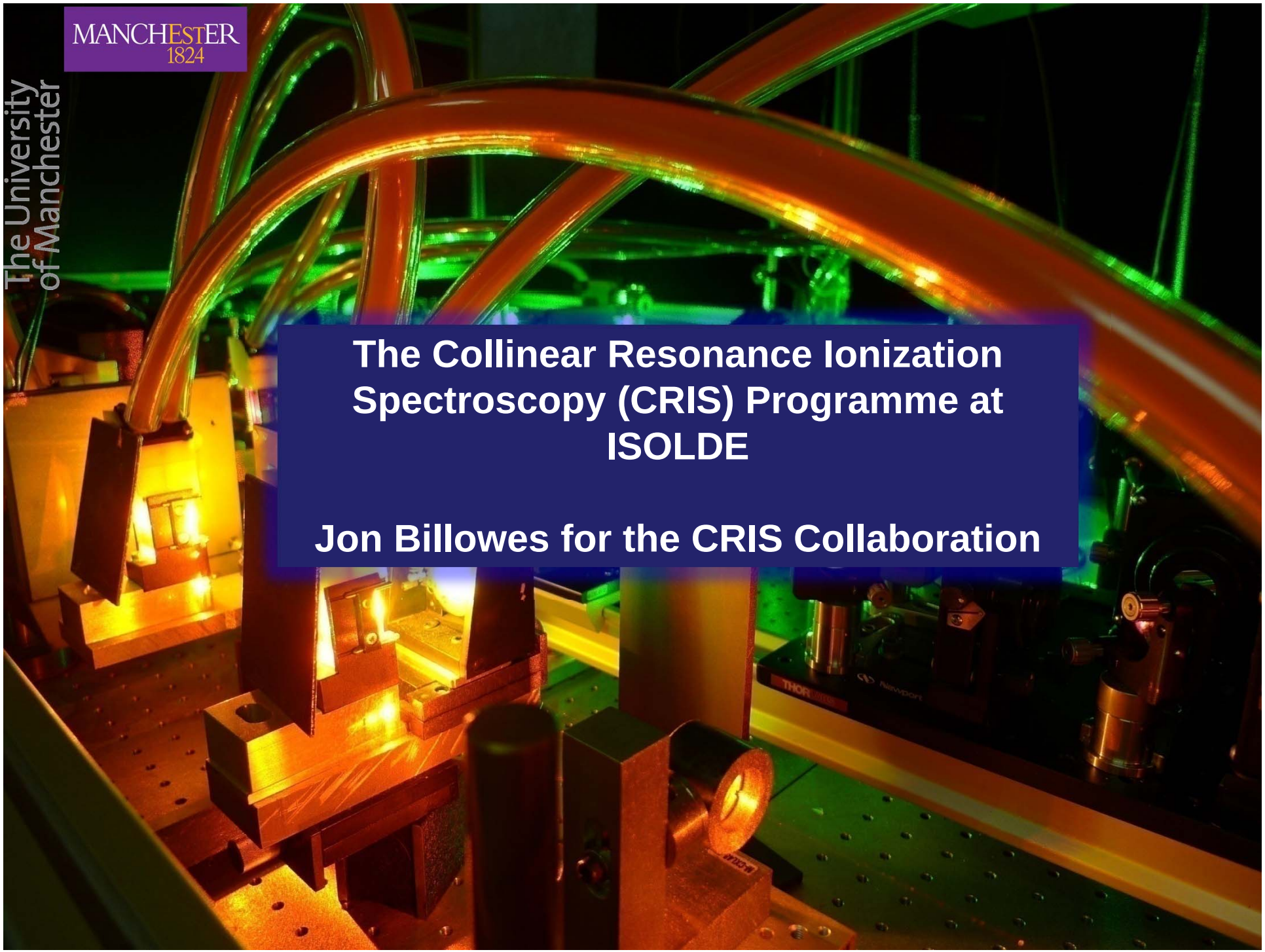
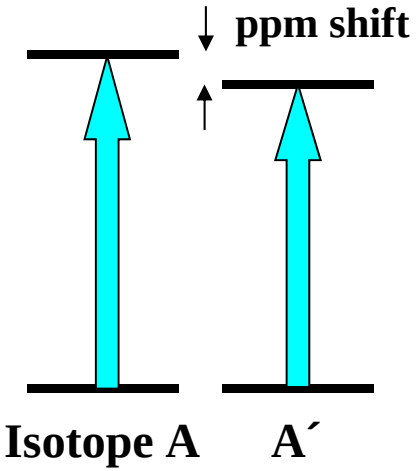


The Collinear Resonance Ionization Spectroscopy (CRIS) Programme at ISOLDE

Jon Billowes for the CRIS Collaboration

Isotope shift of an atomic transition

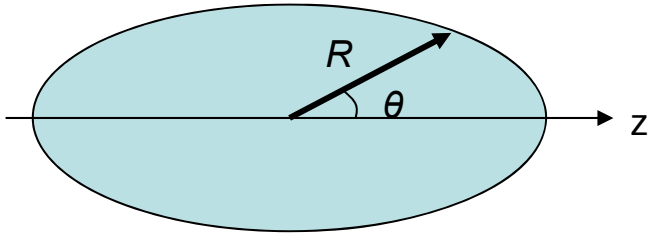


Analysis of shift yields the *change* in nuclear mean square charge radius:

$$\delta\langle r^2\rangle = \langle r^2\rangle^{A'} - \langle r^2\rangle^{A}$$

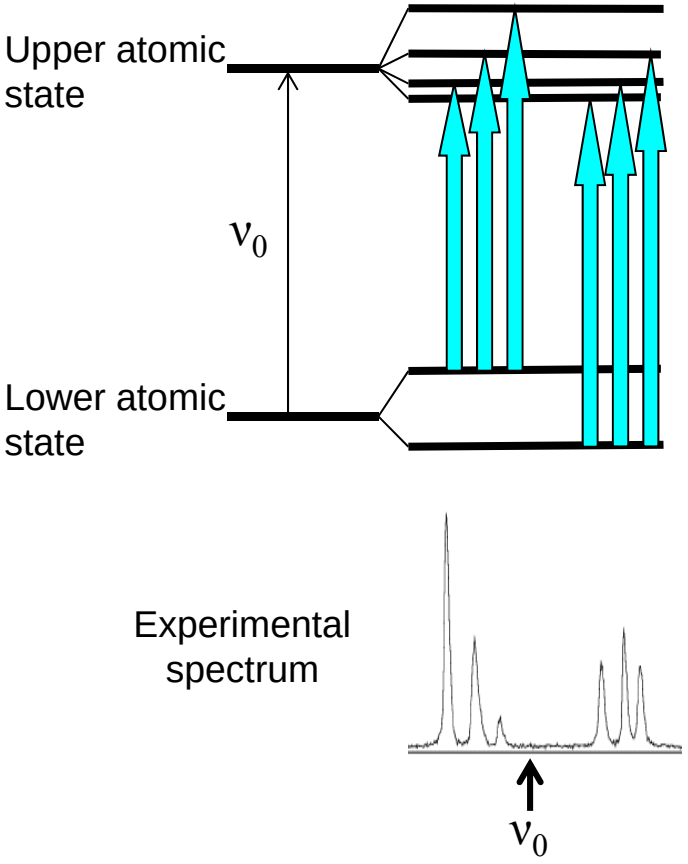
$$\delta\langle r^2\rangle = \delta\langle r^2\rangle_{\mathrm{sph}} + \langle r^2\rangle_{\mathrm{sph}} \frac{5}{4\pi} \delta\langle \beta_2^2\rangle$$

volume deformation



$R = R_0 (1 + \beta_2 Y_{2,0} (\theta,\varphi))$

Hyperfine Structure of atomic transition



Analysis of hyperfine factors

↓

Nuclear spin I

Magnetic moment μ

Quadrupole moment Q_s

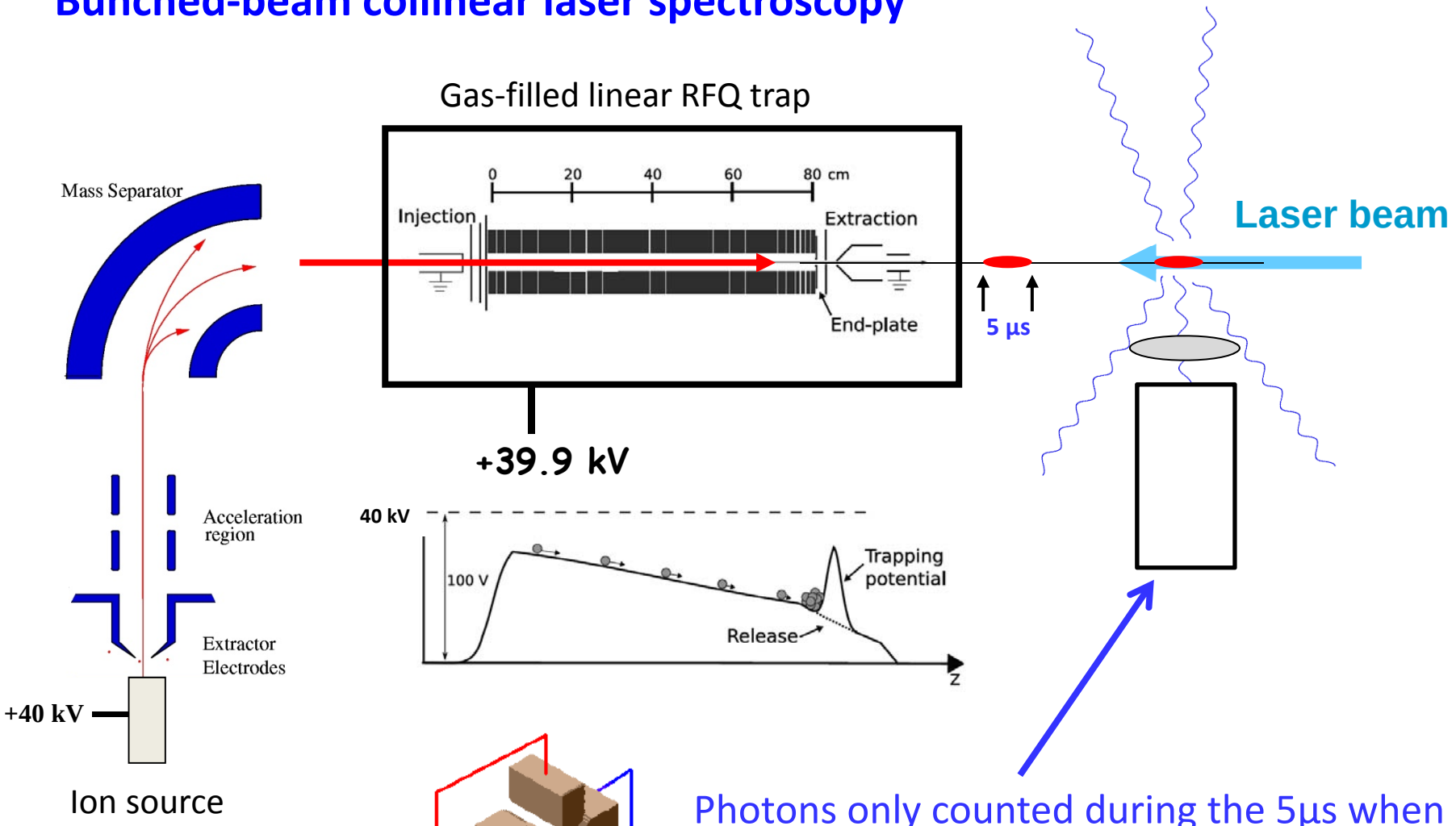
+

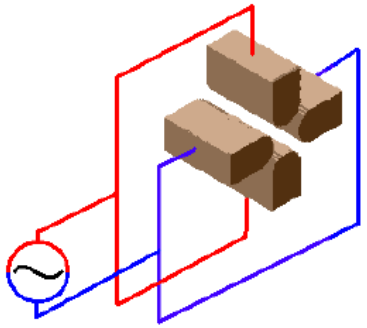
isotope shifts $\delta\langle r^2\rangle$

For measurements on radioactive nuclei, need:

- High sensitivity
- High (sub-Doppler) resolution

High sensitivity method developed at JYFL:
Bunched-beam collinear laser spectroscopy

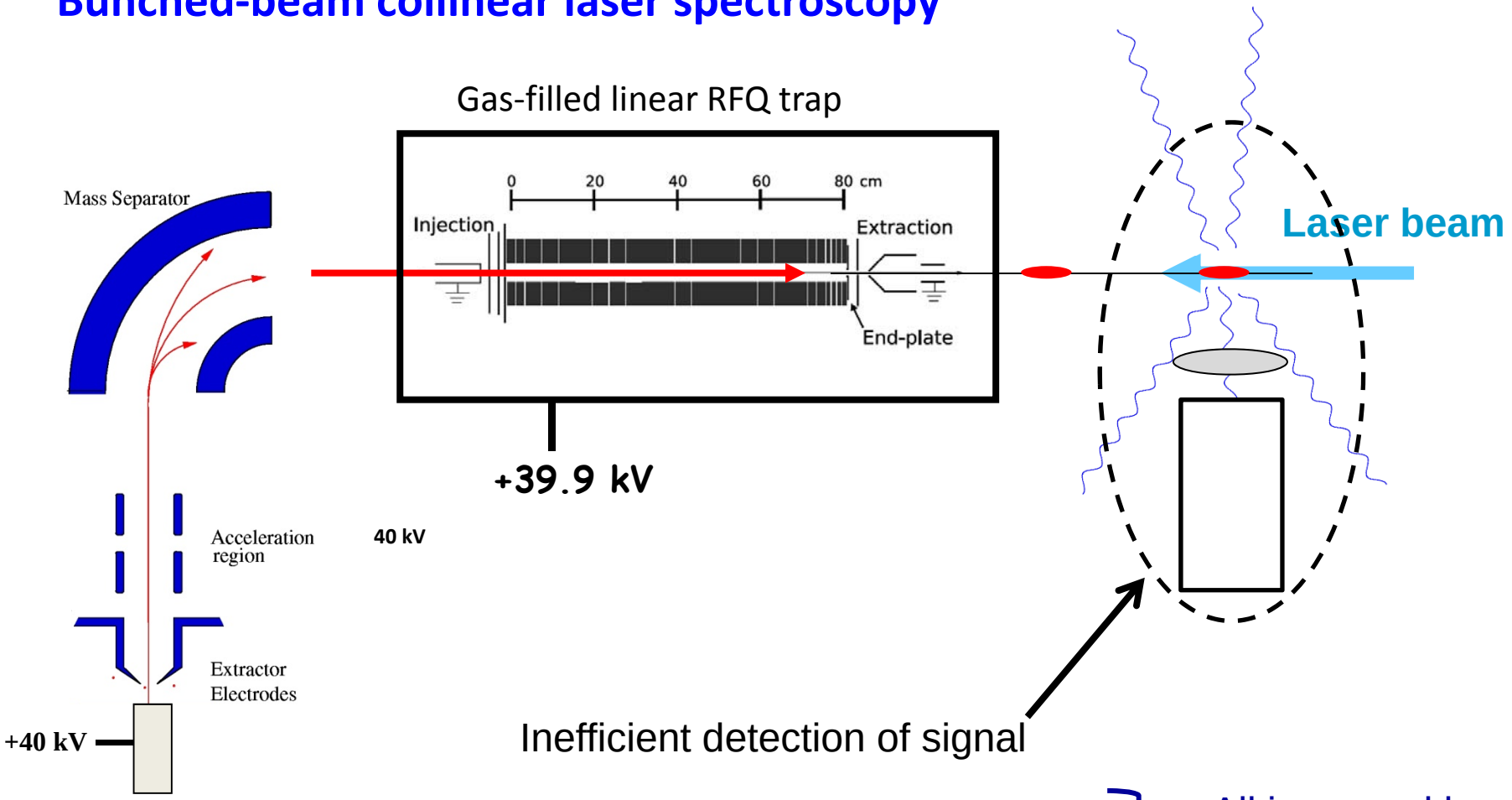




Photons only counted during the 5µs when ion beam passes photomultiplier tube.

50 ms trapping = 10^4 reduction in background compared with a continuous ion beam

High sensitivity method developed at JYFL:
Bunched-beam collinear laser spectroscopy

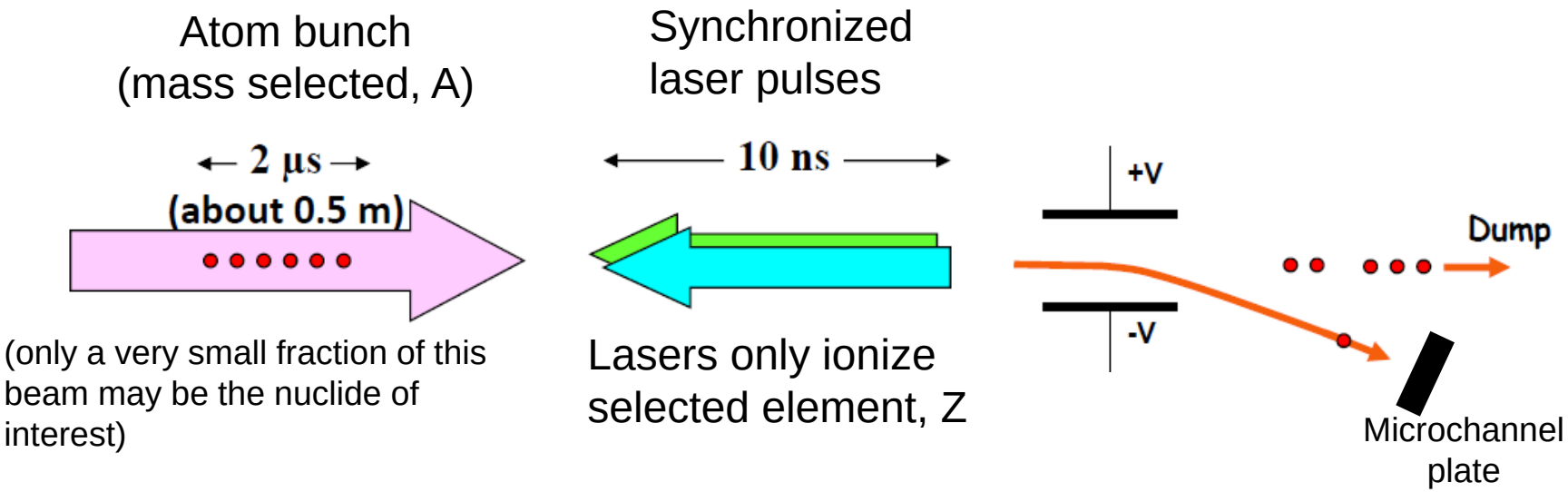


- Small solid angle
- Low quantum efficiency
- Background from laser light

All improved by counting ions instead of photons

Count ions instead:

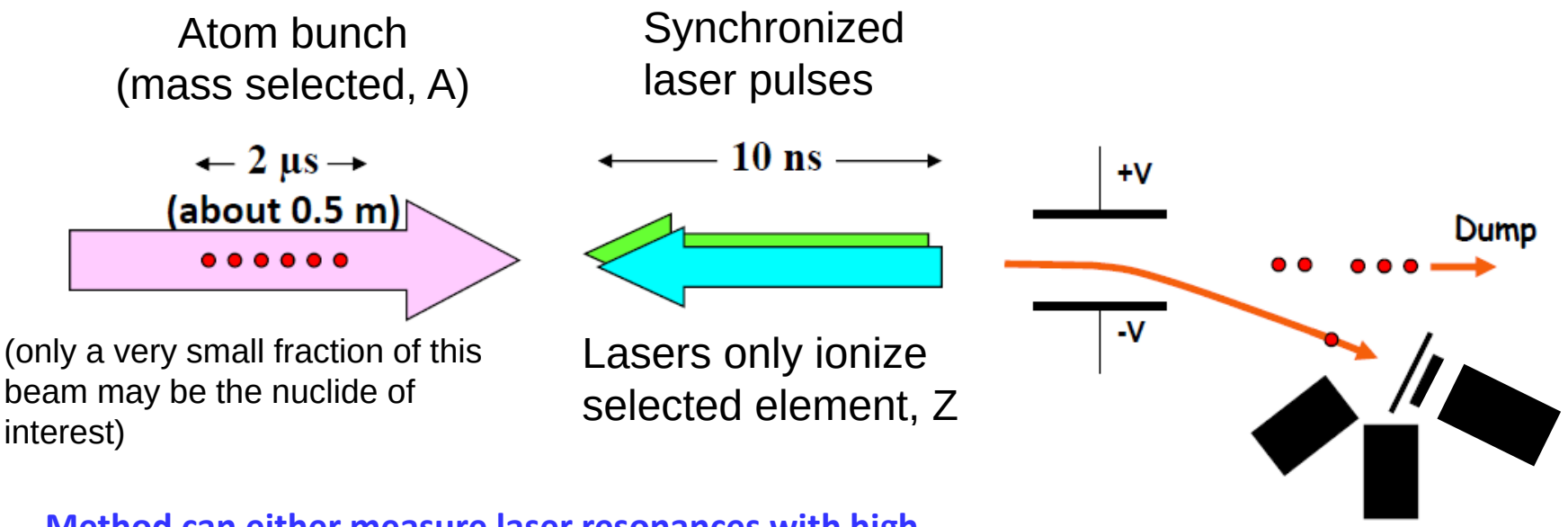
Collinear Resonance Ionization Spectroscopy (CRIS)



Method can either measure laser resonances with high sensitivity and low background → **Ion Counter**

Count ions instead:

Collinear Resonance Ionization Spectroscopy (CRIS)



Method can either measure laser resonances with high sensitivity and low background → **Ion Counter**

or

provide hyper-pure samples of exotic nuclei, for low-background nuclear spectroscopy → **Catcher foil station & Nuclear radiation detectors**

(LANDS: Laser-assisted nuclear decay spectroscopy)

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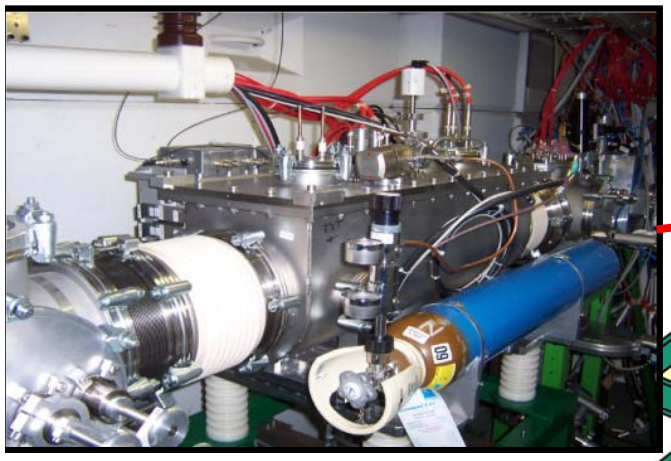
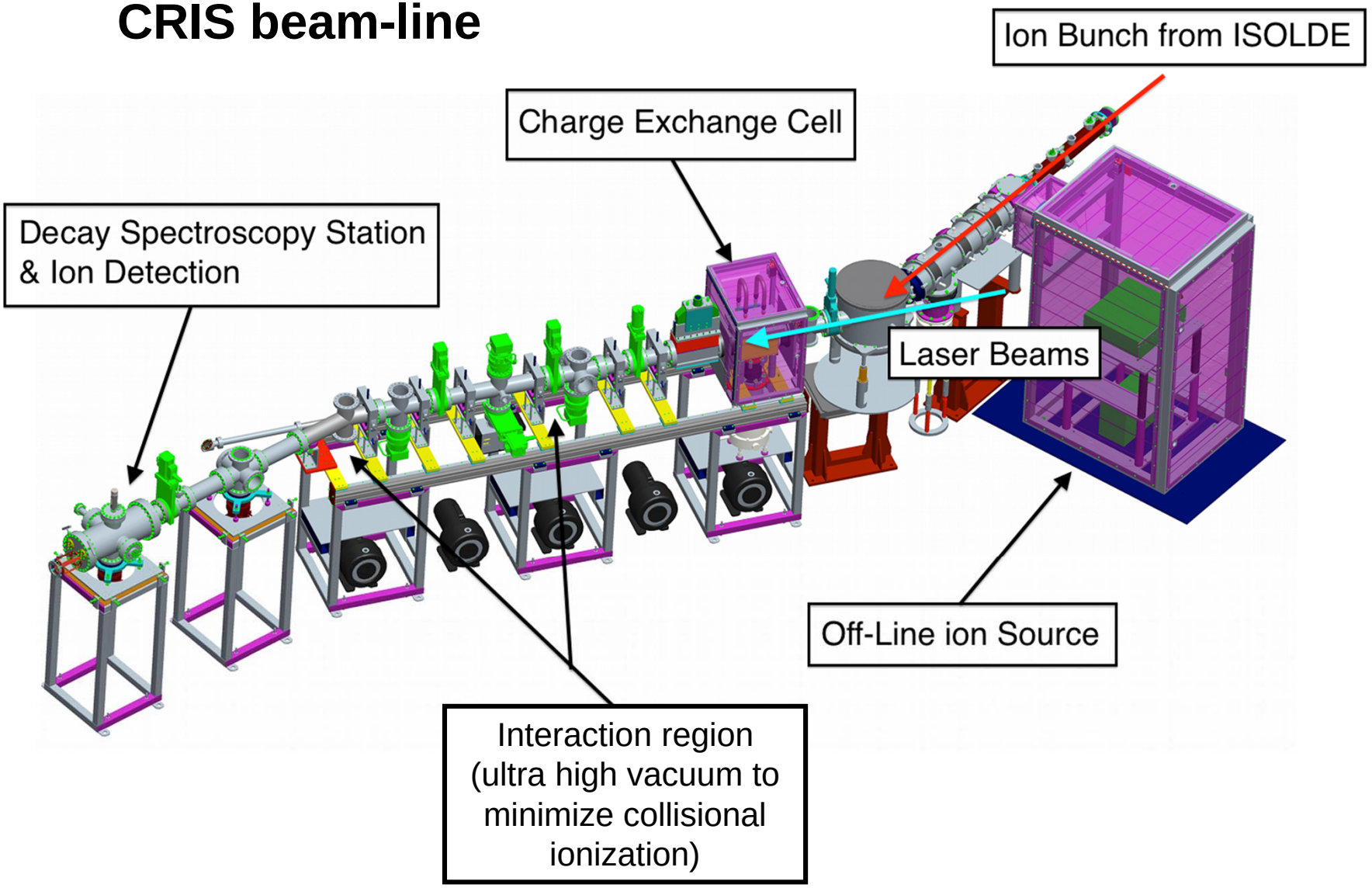
ISOLDE

ISOLDE - CERN

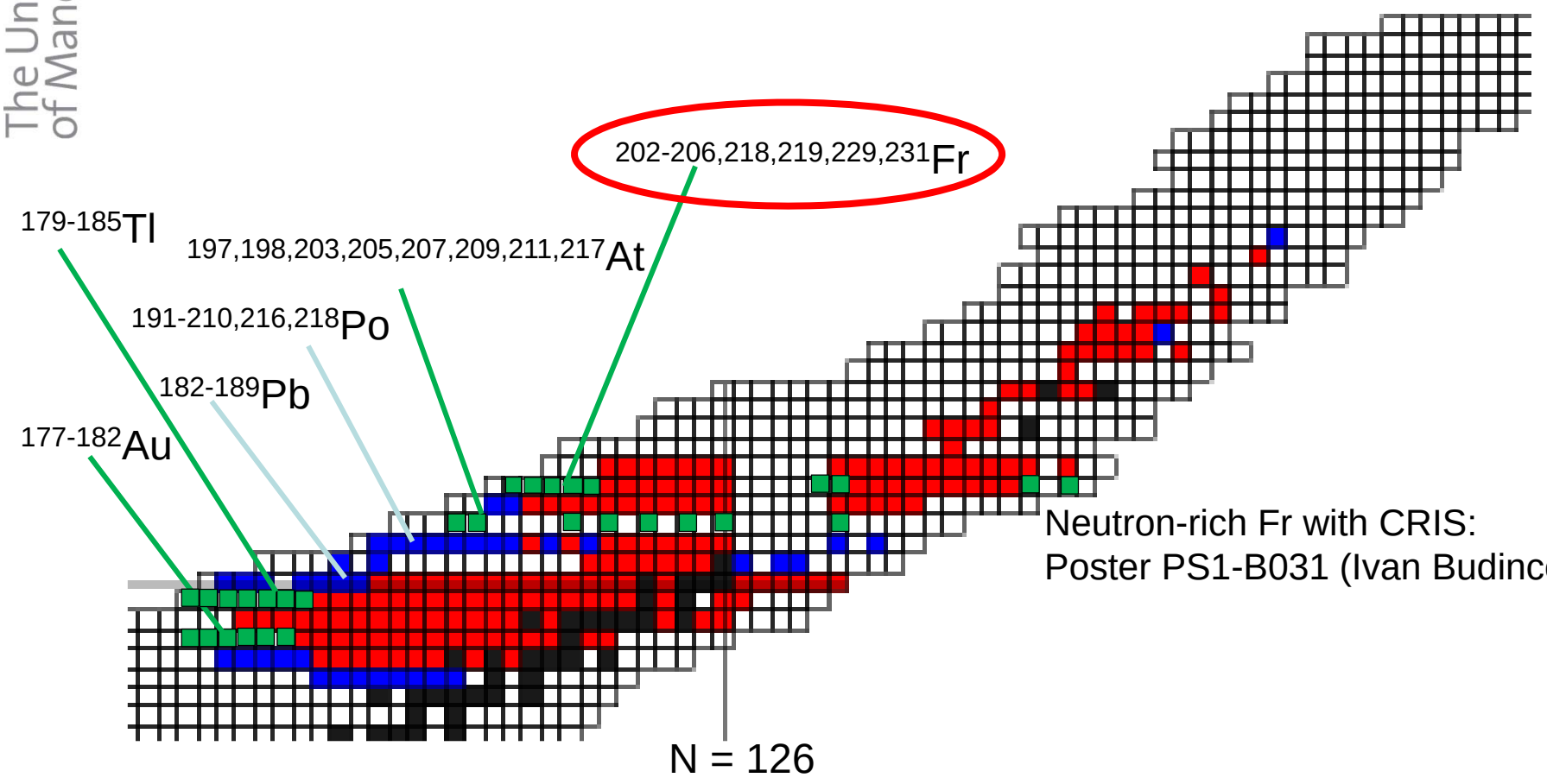


ISCOOL
ion beam
buncher

CRIS beam-line

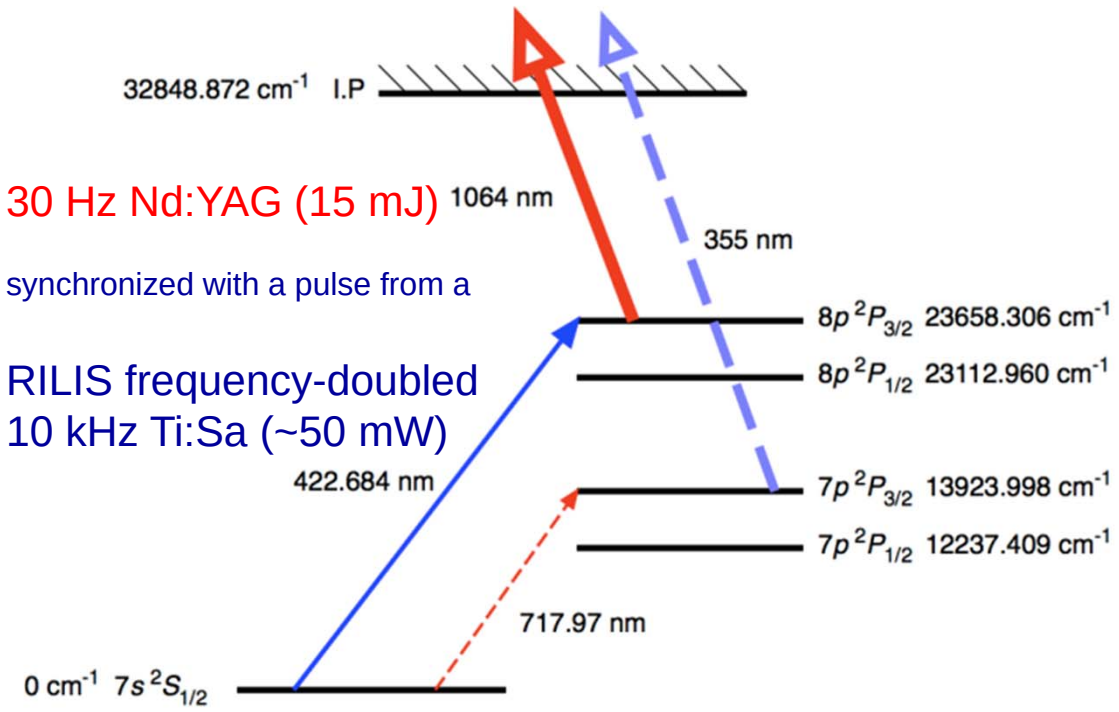


First measurements – francium isotopes



Neutron-rich Fr with CRIS:
Poster PS1-B031 (Ivan Budincevic)

Neutron-deficient Fr isotopes at TRIUMF (high resolution):
A. Voss et al., Phys. Rev. Lett. 111, 122501 (2013)



Francium laser ionization scheme

K.T. Flanagan et al: proposal to INTC to measure Fr isotopes, 2008

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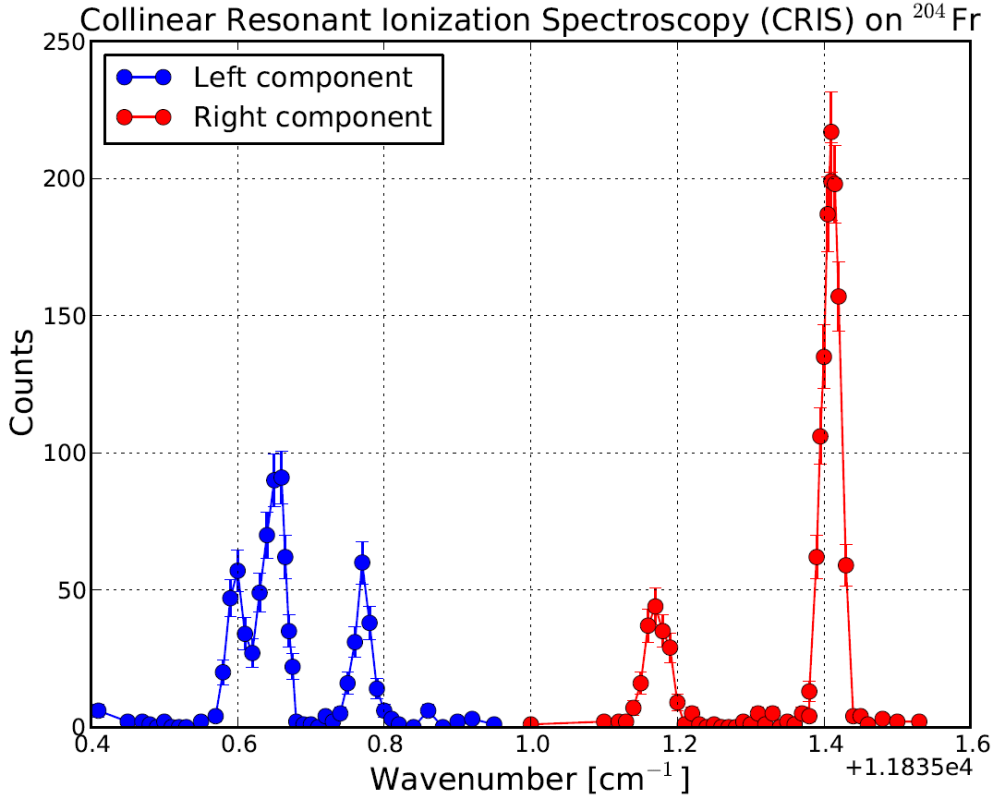
Example spectrum: ^{204}Fr ground state and two isomers



Resolution: limited only by Ti:Sa pulsed laser to 1.5 GHz

Efficiency: 1% - including beam transport, neutralization, ionization and detection

Lowest yield: ^{202}Fr measured with production yield of ~100 atoms/sec

Neutron-deficient isotopes measured: Charge radii and magnetic moments for 202g,202m, 203,204g, 204m1, 204m2, 205, 206g, 206m1, 206m2,

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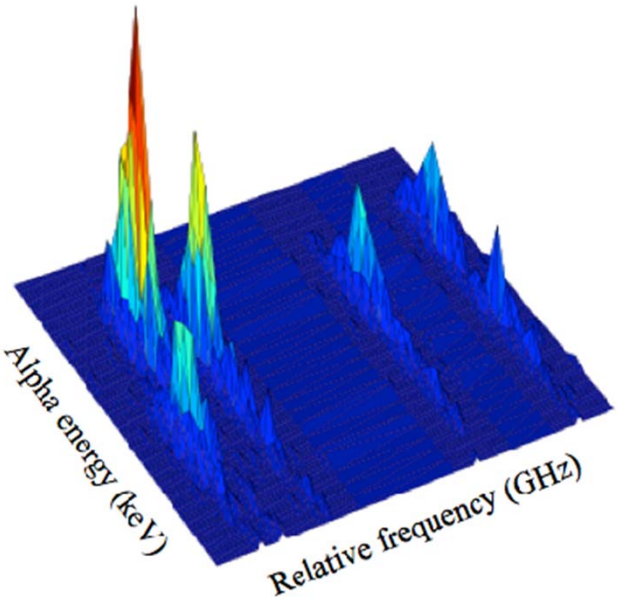
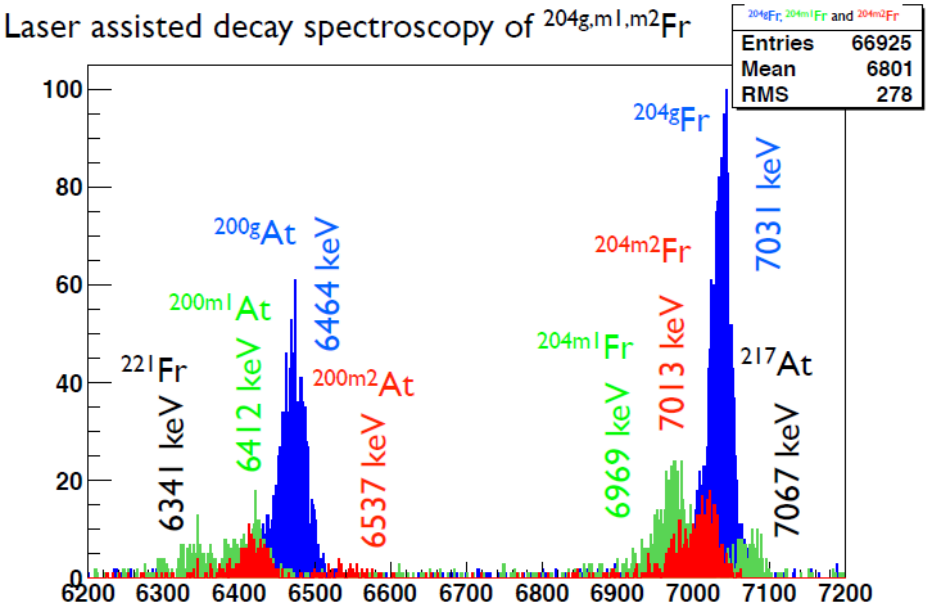
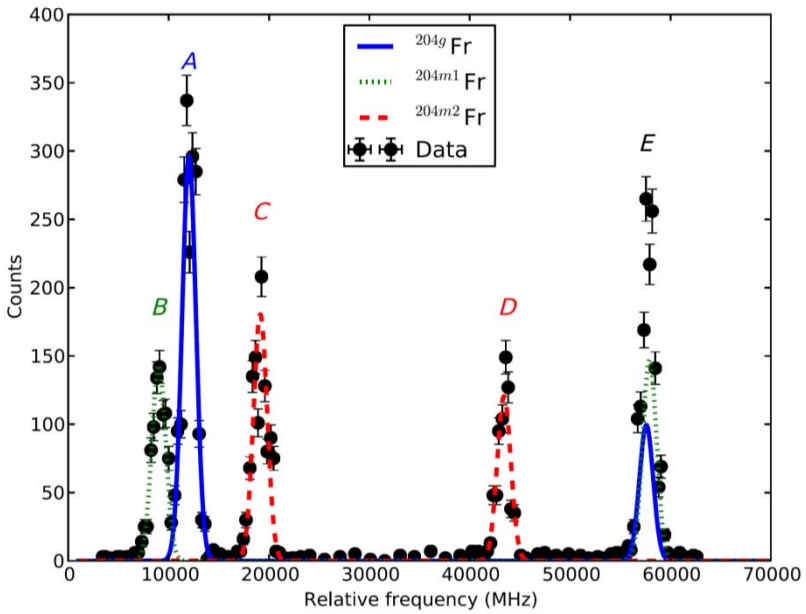
LANDS – laser assisted nuclear decay spectroscopy:

separation of ^{204}Fr ground state and two isomers





Alpha spectrum



Laser resonance spectrum

K.M. Lynch et al., Phys. Rev. X **4** 011055 (2014)

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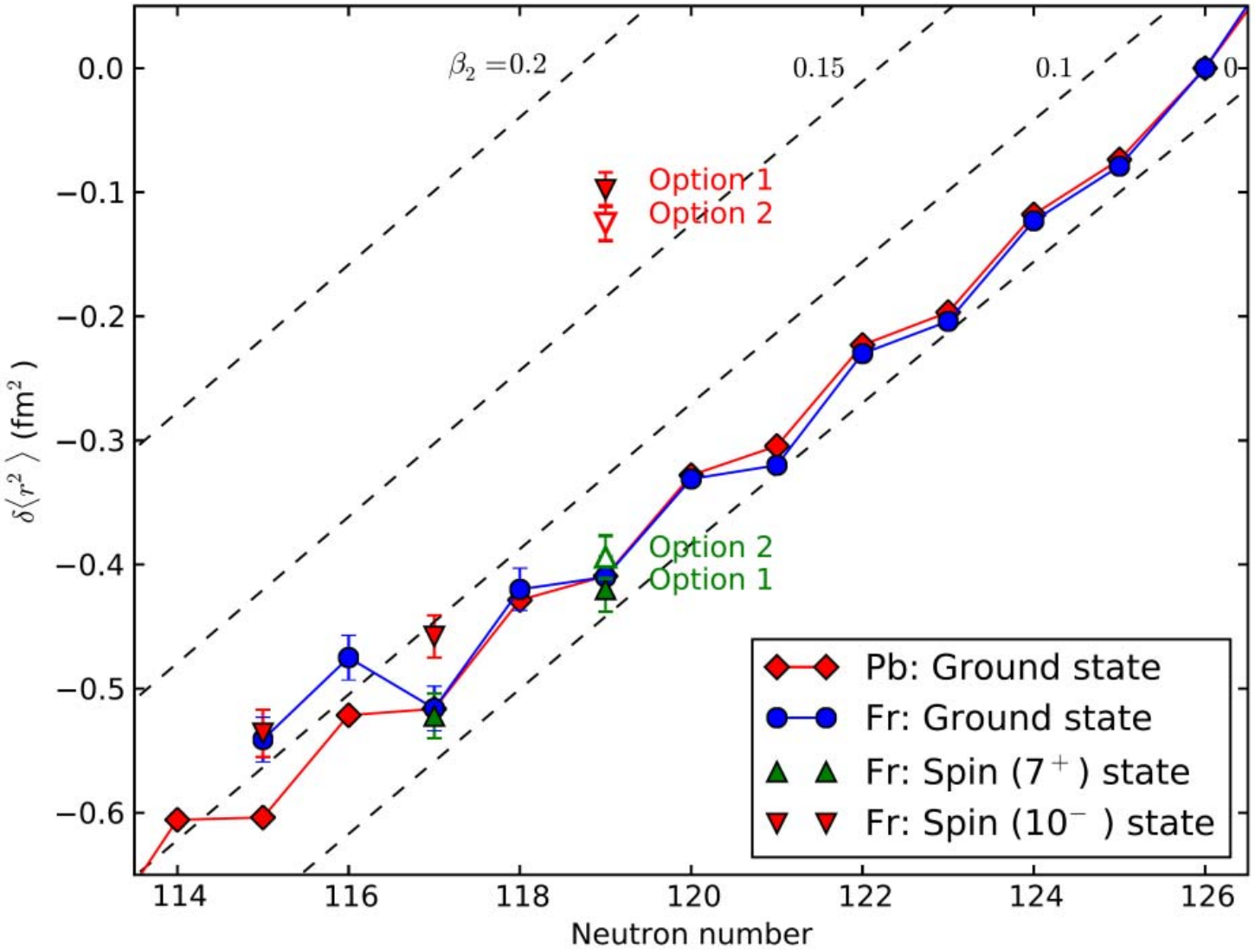
Mean square charge radii of francium isotopes



The CRIS Collaboration

J. Billowes, T.E. Cocolios, K.T. Flanagan, T.J. Procter, A. Smith, I. Strashnov, K.M. Lynch, S. Franchoo, V. Fedosseev, B. Marsh, G. Simpson, M. Bissell, I. Budincevic, R.P. De Groote, S. De Schepper, R.F. Garcia Ruiz, H. Heylen, J. Papuga, G. Neyens, H.H. Stroke, R.E. Rossel, S. Rothe, K. Wendt